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DYNAMICS OF NITROGEN AND PHOSPHOROUS FRACTIONS UNDER INTEGRATED USE OF INORGANIC FERTILIZERS AND ORGANIC MANURE AND THEIR CORRELATION WITH YIELD OF YAM BEAN IN ALFISOLS

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ABSTRACT

The present investigation was carried out for three consecutive years during Kharif season of 2018, 2019 and 2020 at Central Experiment Station Wakawali, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India to study the integrated effect of inorganic fertilizers and organic manure on forms of nitrogen and phosphorous in soils under yam bean cultivation. The levels of nitrogen (80,100,120 kg ha^{-1}), phosphorous (40, 60, 80 kg ha^{-1}), FYM (10, 15, 20 t ha^{-1}), a constant dose of potassium (100 kg ha^{-1}) and an absolute control were distributed in thirteen treatment combinations and replicated thrice in randomized block design.. Among the various nitrogen fractions, total hydrolysable-N was the dominant N fraction. On an average , hydrolysable NH_4-N, amino acid-N. hexosamine-N and unidentified hydrolysable-N contributed about 27.54, 43.07, 10.81 and 18.58 per cent of total hydrolysable-N, respectively. The phosphorous fertilizers applied in different levels along with different FYM levels significantly increased all phosphorous fractions except residual-P, over their initial values and control treatment. The relative abundance of nitrogen fractions was in order of exchangeable NO_3-N < exchangeable NH_4-N < fixed NH_4-N < unidentified non-hydrolysable-N < total hydrolysable-N, while phosphorous fractions was in order of organic-P > residual-P > Fe-P > reductant soluble-P > occluded-P > Al-P > Ca-P > saloid-P. The treatment consisting 120:80:100 N, P_2O_5, K_2O kg ha^{-1} + 20 t FYM ha^{-1} recorded maximum values of phosphorous and nitrogen fractions except exchangeable NH_4-N, exchangeable NO_3-N and unidentified non-hydrolysable-N. The correlation study of nitrogen and phosphorous fractions with yield of yam bean tuber revealed a significant and positive correlation; out of which organic nitrogen fractions such as total hydrolysable-N (r = 0.93 **), hydrolysable NH_4-N (r = 0.96**), Hexosamine-N (r = 0.95**) and amino acid-N (r = 0.94**) recorded highest correlation coefficient values and the Fe-P, Al-P, occluded-P and organic-P reported highest correlation coefficient values as r = 0.94**, r = 0.94**, r = 0.97** and r = 0.98**, respectively. The unidentified nitrogen fractions and saloid-P were observed to be negatively correlated with yam bean yield. The correlation study between nitrogen, phosphorous fractions and soil properties showed positive and significant correlation of almost all fractions with available macronutrients except for unidentified hydrolysable-N, unidentified non-hydrolysable-N and saloid-P which was negatively correlated with available P.

Key words : Nitrogen fractions, Phosphorous fractions, Yam bean, Alfisols.

Introduction

Yam bean (*Pachyrrhizus erosus* L.) is one of the tropical tuber crops that belong to Leguminosae family, majorly used for its edible tuberous root. It mostly goes by local names or indigenous names as Shankalu, Mishrikand, Sankeshalu or Kesaru. Agro-climatic conditions of Konkan *i.e.* hot and humid climate is ideal for commercial cultivation of yam bean. Tubers of yam bean contain 49-58 per cent moisture, 1-3 per cent crude fibre, 8-14 mg 100 g^{-1} ascorbic acid, 2-4 per cent protein, 8-16 per cent starch and 1-4 per cent sugars (Biradar, 2021). The proximity of the Konkan region to metropolitan markets such as Mumbai, Pune and Panaji is an added advantage for marketing of these tubers especially in hotel and tourism industry which is growing at an accelerated rate in Konkan region. The crop has good stress resistant capacity for both biotic and abiotic stresses. It comes up well in comparatively marginal land and does not require great care (Nath *et al.*, 2008). The matured seeds have high content of alkaloids and high level of rotenone which have insecticidal properties (Mukhopadhyay *et al.*, 2008).

Nitrogen is a major nutrient element for living organisms on earth and plays a central role in regulating the composition, structure and functions of ecosystems (Fang *et al.*, 2009). Nitrogen in soil is present in different forms as protein in solid organic form to gaseous form as ammonia. These forms are mainly divided as organic and inorganic nitrogen fractions. Inorganic nitrogen in basically available form of nitrogen which contains ammonium (NH_4), ammonia (NH_3), nitrate (NO_3) and nitrite (NO_2). Organic forms present are mainly proteins, amino acids, humus etc. Organic nitrogen comprises over 90 per cent of the total nitrogen found in soil (Pulford, 1991). Inorganic nitrogen is the main type of soil nitrogen that can be directly absorbed and utilized by plants, but only accounting to 1 per cent in the soil nitrogen (Das *et al.*, 1997).

Organic nitrogen fractions in soil are considered to be the active pools of plant available nitrogen (Sultane, 2008). In bio-solids, the majority of nitrogen added to the soil is in organic forms; the remainder is in inorganic forms. Mineralization of soil organic nitrogen is a key process for supply of nitrogen to tropical crops. The nitrogen mineralization rate determines the availability of nitrogen for plant growth. An understanding of behaviour of nitrogen in lateritic soils is necessary prerequisite for improving growth and yield and improving the production efficiency of nitrogen fertilizer. The continuous application of fertilizers and manures influences various fractions particularly of nitrogen in soil. Transformation of these nitrogen fractions influences nitrogen availability in soil which in turn governs the crop growth and development and quality of produce (Mairan, 2002). The contribution of different forms of nitrogen to mineralizable nitrogen pool must be understood if nitrogen fertilizers are to be used efficiently. Unfortunately, little progress has been made in identifying and measuring an easily mineralizable nitrogen fraction.

Phosphorous ranks second most essential nutrient after nitrogen and plays a vital role in plant growth. Being part of adenosine triphosphate, adenosine diphosphate it takes part in energy transformation in plant cells and acts as energy currency. The availability of phosphorous in soil depends on the fractions, which influence the primary productivity of agricultural ecosystem. The inorganic phosphorous fertilizers and organic manures provides increase in concentration of inorganic phosphorous and organic phosphorus simultaneously in soils (Amaiza, 2012). Inorganic phosphorous is the predominant form of soil phosphorous, constituting 20 to 80 percent of total phosphorous in the surface layer (Tomar, 2003). Compared with other nutrients, phosphorus is least available to plants and is less mobile in soil due to adsorption to iron and aluminum particularly in acidic soils while adsorption to calcium in highly alkaline soils. So, availability of phosphorous is more in neutral soil pH range. Fractionation scheme separate the different phosphorous fractions according to nature, either inorganic or organic and desorption or dissolution, using different extractants with low to high desorption power and dissolutions (Cross and Schlesinger, 1995).

Phosphorous fractions amount and their distribution in the soil change with addition of different types of organic manures and inorganic concentrations. The total inorganic phosphorous is divided into active and inactive forms. The former consists of iron-P, aluminium-P and calcium-P and the latter consists of occluded-P; reductant soluble-P and residual-P (Chang and Jackson, 1957). Active forms are the one that are most available to plants. Active fractions represent labile fraction of phosphorous which means that could be easily taken up by crops in favourable condition. Inactive forms refer to recalcitrant form of phosphorus in soil. The vast majority of soil organic phosphorous occurs in relatively stabilized forms and not rapidly mineralized. Although, total phosphorous may give a total reserve of the nutrients in the soil, it is a poor indicator of the availability level since most of the phosphorus may be fixed or unavailable to the plant. Phosphorous status in soil is therefore assessed more from the relative abundance of different forms (Soremi *et al.*, 2017).

Fractionation study is useful to improve fertilizer use efficiency by assessing optimum amount of fertilizer dose as well as for getting higher yields and rejecting the over application of fertilizers. The continuous addition of organic manures along with chemical fertilizers may stimulate mineralization and immobilization of plant nutrients, thereby affecting their amounts in different organic and inorganic forms in soil. Therefore, the present study was undertaken to investigate the effect of integrated use of organic manure and chemical fertilizers on different forms of nitrogen, phosphorous and their correlation with total tuber yield of yam bean in lateritic soils and soil properties, after addition of their amount for three consecutive years.

Materials and Methods

The field experiment was conducted for three consecutive years *i.e.*, *Kharif* 2018, 2019 and 2020 at the Central Experiment Station, Wakawali, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra, India. In all, thirteen treatment combinations (Table 2) receiving three levels of nitrogen (80,100,120 kg ha^{-1}), phosphorous (40, 60, 80 kg ha^{-1}), FYM (10, 15, 20 t ha^{-1}), a constant dose of potassium (100 kg ha^{-1}) and an absolute control were replicated thrice in randomized block design. The yam bean (*Pachyrhizus erosus* L.), a tuber crop var. *Rajendra Mishrikand*-1 (RM-1) was used as a test crop. The soil samples for nitrogen and phosphorous fractions analysis were collected after harvest of yam bean *i.e.*, 155 days after sowing. The processed samples were analysed for initial physico-chemical properties, nitrogen and phosphorous fractions of soils (Table 1).

The soil samples were analysed by adopting alkaline permanganate method for available nitrogen, Bray and Kurtz method for available phosphorus and ammonium acetate method for available potassium given by Subbiah and Asija (1956), Black (1965) and Jackson (1973), respectively. The individual fractions of nitrogen and total nitrogen content was estimated adopting methods suggested by Hesse (1971) and Chopra and Kanwar (1978), respectively. The samples were distilled in presence of various catalysts and ammonia liberated was collected in boric acid and further titrated against sulphuric acid. For determination of organic nitrogen fractions, hydrolysate was prepared by continuous 12 hr reflux of soil sample with 6N HCL as mentioned by Hesse (1971)

Table 1 : Initial physico-chemical properties of experimental soil.

Parameters	**Content**	**Parameters**	**Content**
Physical properties		Nitrogen fractions (mg kg^{-1})	
Mechanical Analysis		Total N	1407.62
a) Sand (%)	74.25	Inorganic nitrogen fractions	
b) Silt (%)	10.42	Exchangeable NH_4-N	23.86
c) Clay (%)	15.33	Exchangeable NO_3-N	21.54
Textural class	Sandy loam	Fixed NH_4-N	57.17
Particle density (Mg m^{-3})	2.54	Organic nitrogen fractions	
Bulk density (Mg m^{-3})	1.30	Total hydrolysable -N	822.43
Porosity (%)	48.81	Hydrolysable NH_4-N	150.95
MWHC (%)	47.90	Hexosamine-N	79.81
Chemical properties		Amino acid-N	295.64
pH (1:2.5)	5.34	Unidentified hydrolysable-N	296.03
Electrical conductivity (dS m^{-1})	0.03	Unidentified non-hydrolysable-N	482.62
Organic carbon (g kg^{-1})	10.97	Phosphorous fractions (mg kg^{-1})	
Available macronutrients		Total-P	715.82
Available N (kg ha^{-1})	420.57	Fe-P	103.71
Available P_2O_5 (kg ha^{-1})	11.74	Al-P	32.69
Available K_2O (kg ha^{-1})	297.38	Ca-P	15.01
		Saloid-P	6.45
		Occluded-P	41.23
		Reductant soluble-P	101.03
		Residual-P	176.08
		Organic-P	239.62

and used for further distillation with respective catalysts as per the procedure using Kjeldahl steam distillation unit. The inorganic and organic-P fractions content was estimated adopting methods suggested by Peterson and Corey (1966) and Hesse (1971), respectively. The extractant used were 1 M NH_4Cl, 0.5 M NH_4F, 0.7 M NaOH, 0.1 M NaOH, 0.25 M H_2SO_4, 0.3 M Na-citrate for estimation of saloid-P, Al-P, Fe-P, occluded-P, Ca-P and reductant soluble-P, respectively. For determination of total-P digestion was carried out with perchloric acid and nitric acid and colour was developed by Vanado-molybdate solution. Organic-P fraction was determined by ignition method as mentioned by Hesse (1971). The contents of different nitrogen fractions were correlated with tuber yield and various soil properties for study of significance. (Gomez and Gomez, 1984).

Results and Discussion

Initial soil properties

The data pertaining to the initial physico-chemical properties as well as nitrogen fractions are presented in Table 1. The soil of experimental plot was sandy loam in texture, moderately acidic in reaction (5.34) with low electrical conductivity (0.03 dS m^{-1}) having very high content of organic carbon (10.97 g kg^{-1}). It was medium in available nitrogen (420.57 kg ha^{-1}), very low in available phosphorous (11.74 kg ha^{-1}) and high in available potassium (297.38 kg ha^{-1}) content which indicated typical lateritic soils of Konkan region. Salvi *et al.* (2015) similarly observed the soil fertility status of Konkan region of Maharashtra and reported that the soils were medium in available nitrogen and phosphorous content and very high in available potassium content. The above results also corroborate the findings of Rathod *et al.* (2018), Jadhav *et al.* (2019) and Biradar *et al.* (2021) in respect of lateritic soils of Coastal region of Maharashtra. The initial total-N content was 1407.62 mg kg^{-1}, while inorganic nitrogen fractions such as exchangeable NH_4-N, exchangeable NO_3-N and fixed NH_4-N content was 23.86, 21.54 and 57.17 mg kg^{-1}, respectively. As far as organic nitrogen fractions were concerned, it showed the content of total hydrolysable-N (822.43 mg kg^{-1}), hydrolysable NH_4-N (15.95 mg kg^{-1}), Hexosamine-N (79.81 mg kg^{-1}), Amino acid-N (295.64 mg kg^{-1}), Un-identified hydrolysable-N (296.03 mg kg^{-1}) and Unidentified non-hydrolysable-N (482.62 mg kg^{-1}) in soil.

Total-N content and Inorganic nitrogen fractions

According to data presented in Table 2 the amount of total-N and inorganic nitrogen fractions such as exchangeable NH_4-N, exchangeable NO_3-N and fixed NH_4-N increased significantly over their initial values as well as absolute control treatment throughout the observations. The values of total nitrogen and inorganic nitrogen fractions showed slight decrease in respect of absolute control treatment than initial content. The improvement in total-N content from treatments T_2 to T_{13} indicated that any application of nitrogen through inorganic fertilizers alone or in combination with FYM application significantly adds up the total nitrogen content in soil. The higher build-up of total N (1882 mg kg^{-1}) content was recorded due to the treatment receiving highest dose of inorganic nitrogen (120 kg ha^{-1}) and highest level of FYM (20 t ha^{-1}) application which may be due to addition of nitrogen in different forms from decomposed products of FYM. Similar results were reported by Tabassum *et al.* (2010) and Jadhao *et al.* (2019), where they reported significant increase in total nitrogen content under integrated treatments and highest content under treatments receiving highest level of FYM.

In case of inorganic nitrogen fractions the highest content of exchangeable nitrogen forms were noted under combination treatments receiving 15 to 20 t ha^{-1} FYM with higher doses of nitrogen. While, statistically at par content of fixed NH_4-N through treatment combinations indicated similar nitrogen fixation by soil irrespective of application rate which might be, because this particular form represents the nitrogen which is fixed in ammonium form by clay minerals, that does not gets affected by nutrient treatments.

Organic nitrogen fractions

Based on the data from Table 2 the content of active pool of nitrogen consisting total hydrolysable-N, hydrolysable NH_4-N, hexosamine-N and amino acid-N was improved under the treatments receiving FYM along with inorganic fertilizers as it improved organic carbon of soils, which is the actual seat of organic nitrogen in soils.

The difference in unidentified non-hydrolysable-N content was recorded through treatment variations but contents were observed to be statistically non-significant. These results are in accordance with those of Kushwaha *et al.* (2017), who observed that unidentified non-hydrolysable-N content varied from 415 to 602 kg ha^{-1} under various levels of inorganic fertilizers contributing highest content in nitrogen fractions. The significantly highest contents of different nitrogen forms were recovered in treatments (T_8 to T_{13}) receiving combined application of inorganic fertilizers and higher level of FYM (15 to 20 t ha^{-1}). However, the amounts of different forms of nitrogen recovered under inorganic fertilizers treatment containing lowest level nitrogen and phosphorous (T_2)

Table 2 : Effect of various treatments on different forms of nitrogen after harvest of yam bean.

Tr. no.	Total N (mg kg^{-1})	Inorganic nitrogen fractions (mg kg^{-1})			Organic nitrogen fractions (mg kg^{-1})					
		Exch NH_4-N	Exch NO_3-N	Fixed NH_4-N	Total hydrolysable-N	Hydrolysable NH_4-N	Hexosamine-N	Amino Acid-N	Unidentified Hydrolysable -N	Unidentified Non-hydrolysable-N
T_1	1358.93	20.91	20.91	47.04	807.33	154.00	74.67	308.00	270.67	462.75
T_2	1463.47	20.91	26.13	67.95	830.67	177.33	84.00	331.33	238.00	517.81
T_3	1568.00	26.13	36.59	62.72	868.00	203.00	93.33	354.67	217.00	574.56
T_4	1749.37	26.13	52.27	73.17	889.00	233.33	100.33	385.00	170.33	708.79
T_5	1672.53	26.13	52.27	62.72	910.00	249.67	102.67	347.67	210.00	621.41
T_6	1749.37	26.13	57.49	67.95	945.00	252.00	100.33	401.33	191.33	652.79
T_7	1777.07	31.36	73.17	67.95	977.67	284.67	107.33	452.67	133.00	626.92
T_8	1672.53	26.13	52.27	67.95	1082.67	322.00	121.33	497.00	142.33	443.52
T_9	1568.00	31.36	67.95	73.17	1066.33	294.00	107.33	473.67	191.33	329.19
T_{10}	1870.47	41.81	73.17	73.17	1106.00	336.00	130.67	508.67	130.67	576.31
T_{11}	1777.07	62.72	41.81	73.17	1143.33	331.33	126.00	499.33	186.67	456.03
T_{12}	1880.80	73.17	62.72	73.17	1178.33	364.00	128.33	520.33	165.67	493.40
T_{13}	1881.60	67.95	67.95	78.40	1208.67	382.67	130.67	525.00	170.33	458.64
S.E. (±)	82.06	5.84	6.30	4.39	5.49	4.69	2.64	7.34	6.97	81.75
CD (p=0.05)	434.60	30.95	33.39	23.24	29.07	24.83	13.99	38.88	36.90	NS

T_1 = Absolute control; T_2 = 80:40:100 N, P_2O_5, K_2O kg ha^{-1}; T_3 = 100:60:100 N, P_2O_5, K_2O kg ha^{-1}; T_4 = 120:80:100 N, P_2O_5, K_2O kg ha^{-1}; T_5 = 80:40:100 N, P_2O_5, K_2O kg ha^{-1}+10t FYM ha^{-1}; T_6 = 100:60:100 N, P_2O_5, K_2O kg ha^{-1}+10t FYM ha^{-1}; T_7 = 120:80:100 N, P_2O_5, K_2O kg ha^{-1} + 10 t FYM ha^{-1}; T_8 = 80:40:100 N, P_2O_5, K_2O kg ha^{-1}+ 15 t FYM ha^{-1}; T_9 = 100:60:100 N, P_2O_5, K_2O kg ha^{-1} + 15t FYM ha^{-1}; T_{10} = 120:80:100 N, P_2O_5, K_2O kg ha^{-1} + 15 t FYM ha^{-1}; T_{11} = 80:40:100 N, P_2O_5, K_2O kg ha^{-1} + 20t FYM ha^{-1}; T_{12} = 100:60:100 N, P_2O_5, K_2O kg ha^{-1} + 20t FYM ha^{-1}; T_{13} = 120:80:100 N, P_2O_5, K_2O kg ha^{-1}+ 20t FYM ha^{-1}.

Table 3 : Correlation coefficient (r) of nitrogen fractions with yield of yam bean tuber and physico-chemical properties of soils.

Fractions (mg kg^{-1})	Yield (t ha^{-1})	B.D.	P. D.	Porosity	MWHC	pH	EC	Avail N	Avail P_2O_5	Avail K_2O	Org C
Total N	0.82**	-0.67**	-0.12	0.67**	0.79**	0.86**	-0.22	0.79**	0.69**	0.83**	0.71**
Exchangeable NH_4-N	0.67**	-0.73**	-0.59**	0.68**	0.68**	0.68**	-0.36	0.84**	0.83**	0.83**	0.94**
Exchangeable NO_3-N	0.82**	-0.66**	-0.13	0.66**	0.75**	0.79**	0.14	0.73**	0.42**	0.76**	0.48*
Fixed NH_4-N	0.83**	-0.67**	-0.11	0.68**	0.90**	0.70**	0.08	0.74**	0.60**	0.75**	0.71**
Total hydrolysable N	0.93**	-0.93**	-0.46**	0.88**	0.85**	0.82**	-0.23	0.95**	0.63**	0.98**	0.96**
Hydrolysable NH_4-N	0.96**	-0.92**	-0.34	0.89**	0.88**	0.86**	-0.23	0.94**	0.65**	0.99**	0.91**
Hexosamine-N	0.95**	-0.87**	-0.27	0.85**	0.88**	0.84**	-0.32	0.88**	0.60**	0.95**	0.90**
Amino acid-N	0.94**	-0.88**	-0.37	0.84**	0.84**	0.89**	-0.14	0.93**	0.55**	0.95**	0.90**
Unidentified hydrolysable N	-0.81**	0.60**	-0.12	-0.61**	-0.70**	-0.87**	0.04	-0.65**	-0.35	-0.71**	-0.52**
Unidentified nonhydrolyzable N	-0.40*	0.59**	0.60**	-0.52**	-0.36	-0.20	0.003	-0.51**	-0.15	-0.48*	-0.59**

*Significant at 5% level, **Significant at 1% level.

and control did not differ significantly among themselves. Application of highest level of nitrogen and phosphorous along with highest level of FYM (T_{13}) resulted in highest amounts of nitrogen fractions followed by treatments T_{12} and T_{10} in maximum fractions. This might be due to organic residue addition and accumulation under higher FYM application contributing higher buildup of nitrogen forms in soil upon decomposition and thus an increase of 55.85 - 474.00, 2.27 - 49.31, 4.59 - 51.63, 5.55 - 21.23, 8.24 - 386.24, 3.05 - 231.72, 4.19 - 50.86 and 12.36-229.36 mg kg^{-1} in total-N, exchangeable NH_4-N, exchangeable NO_3-N, fixed NH_4-N, total hydrolysable-N, hydrolysable NH_4-N, hexosamine-N and amino acid-N, respectively was observed over their initial values. The significant increase in all forms of nitrogen throughout the increasing levels of FYM was observed, except in unidentified hydrolysable-N and unidentified nonhydrolyzable-N fraction where lowered contents were observed in combination treatment while higher contents were reported in sole inorganic fertilizers application. Similar increase was observed by Jadhao *et al.* (2019) who reported significant increase nitrogen fractions under application of 100 per cent NPK with FYM in rice wheat cropping sequence on Vertisols. Joke (2020) also reported highest content of nitrogen fractions under treatment receiving 100 per cent NPK through inorganic inputs under turmeric cultivation in lateritic soils of Konkan region.

The amount and percent contribution of nitrogen fractions is presented in Fig. 1. It was clearly observed that total hydrolysable -N contributed highest while exchangeable NH_4-N contributed least *i.e.*, 59 per cent and 2 per cent of total-N, respectively. Among the various organic nitrogen fractions amino acid-N was the dominant fraction accounting for 43.07 per cent of total hydrolysable nitrogen followed by hydrolysable NH_4-N, unidentified hydrolysable-N and hexosamine-N with contributions ranged between 19.08 to 31.66 per cent, 11.81 to 33.53 per cent and 9.25 to 11.81 per cent of total hydrolysable-N content, respectively. Amino acid-N was observed to be the dominant organic nitrogen fraction whereas, hexosamine-N was least. The pictorial representation given here denotes that maximum portion of nitrogen applied to soil forms acid soluble organic fraction of soil *i.e.*, total hydrolysable NH_4-N followed by acid insoluble form of nitrogen *i.e.*, unidentified non-hydrolysable-N form. It also denoted that long term application of NPK and organic manures improves the labile nitrogen pool.

Total phosphorous content

The considerable increase in total phosphorus content (1049.87 mg kg^{-1}) has been noted under integrated treatments over control and sole inorganic fertilizer application treatments. The highest total phosphorous was recorded under treatment receiving highest level of FYM (20 t ha^{-1}) along with highest rate of inorganic phosphorous *i.e.*, 80 kg ha^{-1}. It was statistically at par with treatments receiving same level of FYM, but reduced levels of phosphorous. This might be due to addition of extra phosphorous through organic manure upon decomposition and higher release of native phosphorous due to decomposing microbial activity. Sharma *et al.* (2009) observed significant increase in total-P content of soils

Table 4 : Effect of various treatments on different forms of phosphorous in yam bean cropping.

Tr. no.	Total-P	Phosphorous fractions (mg kg^{-1})							
		Fe-P	Al-P	Ca-P	Saloid-P	Occluded-P	Reductant soluble-P	Residual-P	Organic-P
T_1	710.39	99.09	27.88	13.02	7.83	47.50	108.22	173.67	252.05
T_2	729.25	111.22	30.01	16.72	8.58	50.98	111.24	117.96	263.68
T_3	729.25	115.22	32.96	18.50	9.41	53.41	113.26	96.25	286.61
T_4	735.54	120.25	35.64	18.72	10.23	56.14	120.38	76.37	294.16
T_5	823.55	125.36	36.53	19.46	13.05	58.39	125.06	124.23	325.11
T_6	867.56	130.83	33.30	19.46	11.47	60.59	126.07	151.32	334.51
T_7	880.13	138.90	40.31	18.13	14.69	64.33	128.74	131.61	343.43
T_8	943.00	138.16	42.50	20.42	14.21	69.78	132.91	160.63	364.38
T_9	848.70	131.05	38.38	17.46	12.15	63.49	131.18	85.77	369.20
T_{10}	861.27	148.89	44.15	29.53	15.45	70.61	128.30	50.08	374.26
T_{11}	999.58	144.97	40.93	22.94	13.87	67.92	135.07	206.39	371.13
T_{12}	1043.59	155.10	41.47	26.79	11.33	67.81	163.01	202.84	375.24
T_{13}	1049.87	158.66	44.63	28.05	12.70	69.47	138.60	218.32	379.44
S.E. (±)	14.24	0.79	0.77	0.59	0.63	0.33	5.75	16.15	1.06
CD (P=0.05)	75.40	4.19	4.06	3.10	3.32	1.76	30.47	85.54	5.61

T_1 = Absolute control; T_2 = 80:40:100 N, P_2O_5, K_2O kg ha^{-1}; T_3 = 100:60:100 N, P_2O_5, K_2O kg ha^{-1}; T_4 = 120:80:100 N, P_2O_5, K_2O kg ha^{-1}; T_5 = 80:40:100 N, P_2O_5, K_2O kg ha^{-1} +10t FYM ha^{-1}; T_6 = 100:60:100 N, P_2O_5, K_2O kg ha^{-1} +10t FYM ha^{-1}; T_7 = 120:80:100 N, P_2O_5, K_2O kg ha^{-1} + 10 t FYM ha^{-1}; T_8 = 80:40:100 N, P_2O_5, K_2O kg ha^{-1}+ 15 t FYM ha^{-1}; T_9 = 100:60:100 N, P_2O_5, K_2O kg ha^{-1} + 15t FYM ha^{-1}; T_{10} = 120:80:100 N, P_2O_5, K_2O kg ha^{-1} + 15 t FYM ha^{-1}; T_{11} = 80:40:100 N, P_2O_5, K_2O kg ha^{-1} + 20t FYM ha^{-1}; T_{12} = 100:60:100 N, P_2O_5, K_2O kg ha^{-1} + 20t FYM ha^{-1}; T_{13} = 120:80:100 N, P_2O_5, K_2O kg ha^{-1} + 20t FYM ha^{-1}.

due to increased levels of fertilizers in acid Alfisols. Sharma and Paliyal (2014) also noted significantly highest total-P content due to application of 100 per cent NP + FYM at harvest of wheat in Typic Ustipsamments.

Active pool of phosphorous

The different forms of phosphorous as influenced by various treatments are presented in Table 4. The amount of phosphorous recovered under various fractions varied considerably depending upon the treatments given to yam bean crop. The amount of available forms of phosphorous ranged from 99.09 to 158.66 mg kg^{-1} for Fe-P, 27.88 to 44.63 mg kg^{-1} for Al-P, 13.02 to 29.53 mg kg^{-1} for Ca-P and 7.83 to 15.45 mg kg^{-1} for saloid-P, content. The highest content of Fe-P fraction was reported which may be due to lateritic nature of soils (soil under study) that are reported to retain larger amount of phosphorus as Fe-P and Al-P, irrespective of nature and kind of added fertilizer due to more stabilized nature of iron and aluminium under acidic pH. The highest content of Al-P fraction was reported by Sihag *et al.* (2005) under treatment receiving FYM @ 15 t ha^{-1} along with inorganic fertilizers. The amount of phosphorus recovered in total-P, Fe-P, Al-P and Ca-P forms increased significantly over their initial and control treatment values due to sole inorganic and integrated treatments. The magnitude of increase in content was more in treatments receiving organic manures along with inorganic fertilizers than the treatments receiving only inorganic inputs. The maximum values of fractions were reported due to treatment receiving 120:80:100 N, P_2O_5, K_2O kg ha^{-1} + 20 t FYM ha^{-1} followed by treatment containing 120:80:100 N, P_2O_5, K_2O kg ha^{-1} + 15 t FYM ha^{-1}. The saloid-P, which is the most easily available form of phosphorus was observed to be improved under integrated treatments which indicated higher availability of this fraction for assimilation by plant. Similar results of active phosphorous fractions were also reported by Trivedi *et al.* (2010) in Alfisols.

Inactive pool of phosphorous

From the data in Table 4, the ranges of unavailable forms of phosphorous were, 47.50 to 70.61 mg kg^{-1} for occluded-P, 108.22 to 163.01 mg kg^{-1} for reductant soluble-P and 76.37 to 218.32 mg kg^{-1} for residual-P content.

The above results indicated that along with active pool of phosphorous the treatment variations significantly increased the inactive pool of phosphorous. The treatments receiving FYM @ of 15 and 20 t ha^{-1} reported statistically at par results for occluded-P, reductant soluble-P and residual-P content which might be due to well-known behaviour phosphorous to get fixed or strongly adsorbed on minerals after application in soils through fertilizers. The release of this form of phosphorous depends on concentration of soluble phosphorous in soil solutions. The application of FYM helps to improve microbial activity in soils that will help in release of inactive forms of phosphorous. The similar results were reported by Karle (2004), who noted highest occluded-P, reductant soluble-P and residual-P content under poultry manure application followed by vermicompost and FYM in decreasing order.

Organic phosphorous content

The after-harvest content of organic phosphorous fraction was evidently noted under treatment receiving highest doe of inorganic phosphorous (80 kg ha^{-1}) along with highest level of FYM *i.e.*, 20 t ha^{-1}, which was statistically at par with treatment receiving reduced level of inorganic phosphorous (60 kg ha^{-1}) with similar FYM level and even with treatment receiving same inorganic phosphorous but reduced level of FYM which is 15 20 t ha^{-1}. The results clearly indicated that organic manure application through FYM results in significant improvement of organic forms of phosphorous which may contain phytin, ADP, ATP etc. that helps in good plant growth resulting into improved yield. Talshilkar *et al.* (2006) mentioned organic-P content ranged from 247 to 381 mg kg^{-1} in lateritic soils of Konkan region in moderately acidic soils.

Averaged across treatments, saloid-P constituted about 1% of the total-P which could be due to the high phosphorous fixing nature of the soil (Fig. 1). The residual-P, reductant soluble-P, occluded-P and Ca-P accounted for 16, 15, 7 and 3% of total-P, respectively. The Fe-P and Al-P accounted for nearly 15 and 4 % while organic-P reported 39% of total-P, which may be due to lateritic soil type, which retain high phosphorous in these forms irrespective of fertilizers added. Organic-P was observed to be most dominant fraction contributing about 39 % of total-P which might be due to higher application of organic manures resulting in higher conversion of applied phosphorous in organic forms.

Correlation of nitrogen fractions with yield of the crop and soil properties

The data showed that nearly all the fractions of

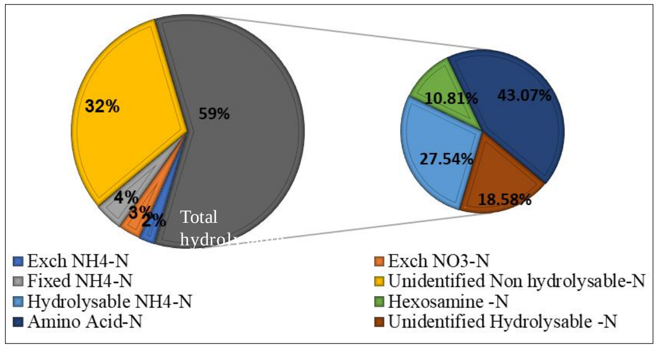

Fig. 1 : Percent contribution of nitrogen fractions in total-N content.

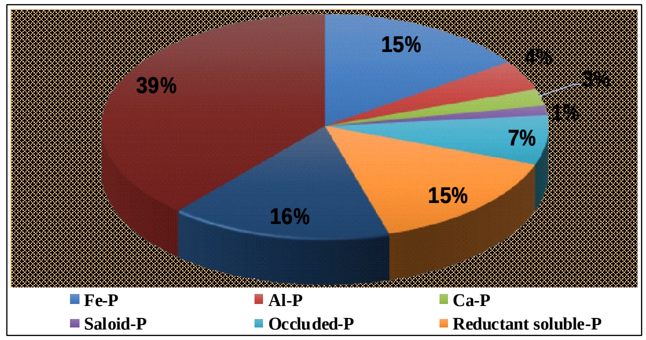

Fig. 2 : Percent contribution of phosphorous fractions in total phosphorous.

nitrogen had positive and significant relationship with yield of yam bean tuber. In case of inorganic nitrogen fractions total-N, exchangeable NH_4-N, exchangeable NO_3-N and fixed NH_4-N had r values as 0.82**, 0.67**, 0.82** and 0.83**, respectively. All the inorganic nitrogen fractions showed positive correlation at both 5 and 1 per cent level of significance. In respect of organic nitrogen fractions, the total hydrolysable-N (r =0.93**), hydrolysable NH_4-N (r = 0.96**), hexosamine-N (r = 0.95**) and amino acid-N (r = 0.94**) showed significantly positive correlation with yam bean tuber yield. Only the unidentified hydrolysable N (r = -0.81**) showed negative correlation at 5 per cent level of significance and unidentified non-hydrolysable N (r = -0.40*) showed significant and negative correlation with total yield of yam bean. The data indicated that yield of yam bean was increased with decrease in the unidentified hydrolysable-N and unidentified non-hydrolysable N fractions. Similar results were reported by Palwade (2015), who reported a positive and significant correlation between nitrogen fractions and soyabean yield. The organic nitrogen fractions reported best correlation with yield of yam bean as coefficient correlation values as r = 0.96**, r = 0.95**, r = 0.94** and r = 0.93** under hydrolysable NH_4-N, hexosamine-N, amino acid-N and total hydrolysable-N fractions, respectively.

It was observed from the data that the significant

Table 5 : Correlation coefficient (r) between nitrogen fractions and yield of tuber physico-chemical properties of soils.

Fractions (mg kg^{-1})	Yield (t ha^{-1})	B.D.	P. D.	Porosity	MWHC	pH	EC	Avail N	Avail P_2O_5	Avail K_2O	Org C
Total-P	0.83**	-0.92**	-0.34	0.89**	0.78**	0.81**	-0.19	0.92**	0.65**	0.94**	0.90**
Fe-P	0.94**	-0.88**	-0.28	0.86**	0.89**	0.90**	-0.16	0.95**	0.69**	0.98**	0.88**
Al-P	0.94**	-0.85**	-0.18	0.83**	0.86**	0.85**	-0.27*	0.85**	0.54**	0.91**	0.82**
Ca-P	0.80**	-0.65**	-0.33	0.61**	0.75	0.70**	-0.40	0.79*	0.74**	0.82**	0.80**
Saloid-P	0.59**	-0.29	0.13	0.29	0.49*	0.64**	-0.06	0.41**	0.23	0.41**	0.27**
Occluded-P	0.97**	-0.89**	-0.19	0.88**	0.86**	0.88**	-0.15	0.88**	0.46*	0.95**	0.82**
Reductant soluble-P	0.78**	-0.83**	-0.38	0.81**	0.70**	0.74**	-0.17	0.80**	0.68**	0.88**	0.81**
Residual-P	0.14	-0.43*	-0.32	0.39*	0.13	0.29	-0.21	0.44*	0.43*	0.39*	0.52**
Organic-P	0.98**	-0.95**	-0.29	0.94**	0.90**	0.83**	-0.09	0.90**	0.46*	0.97**	0.83**
Organic carbon content (g kg^{-1})	0.82**	-0.86**	-0.52**	0.81**	0.81**	0.74**	-0.35	0.90**	0.71**	0.91**	1.00

*Significant at 5% level, **Significant at 1% level.

and negative correlation was recorded in respect of bulk density, negative and non-significant correlation was recorded in respect of particle density while significant and positive correlation was recorded in respect of porosity and maximum water holding capacity of soils for most of the nitrogen fractions except for unidentified hydrolysable and non-hydrolysable N. Regarding the correlation of nitrogen fractions with chemical properties of soil a positive and significant correlation was observed for pH of soils except for unidentified hydrolysable and non-hydrolysable-N where negative correlation was observed. However, a highly non-significant and negative correlation was observed in case of electrical conductivity of soils for most of the nitrogen fractions. The correlation of nitrogen fractions with available macronutrient status and organic carbon content at harvest of yam bean clearly showed a significant and positive correlation for almost all the nitrogen fractions except for unidentified hydrolysable and non-hydrolysable-N fractions in which significant and negative relation was recorded for available nitrogen (r = -0.65**, -0.51**), potassium (r = -0.71**, -0.48**) and organic carbon (r = -0.52**, -0.59**) content of soils. Biradar *et al*. (2021) reported highly significant and positive correlation of organic carbon (r = 0.82**), available nitrogen (r = 0.89**), available phosphorous (r = 0.94**) and available potassium (r = 0.95**) content of soil with total tuber yield of yam bean in Coastal region of Maharashtra. A non-significant and negative correlation was recorded between unidentified hydrolysable-N, unidentified non-hydrolysable-N, and available phosphorous content (r = -0.35, -0.15) of soils, respectively.

Among the total hydrolysable-N fraction (amino acid-N, hydrolysable NH_4-N and unidentified hydrolysable-N), the hydrolysable NH_4-N and amino acid-N fractions have been recognized to be the most important nitrogen fraction with respect to mineral N (Tabassum *et al*., 2010).

Relationship between phosphorous fractions with yield and soil properties

The correlation coefficient values were computed between inorganic, organic and total-P and yield of the yam bean crop. Except the residual-P fraction all the inorganic and organic fractions and total-P content of soil showed positive and significant correlation with yield denoting major contribution of phosphorous forms in improving yield. The inorganic fractions like occluded-P, Fe-P and Al-P reposted highest correlation values as r = 0.97**, r = 0.94** and r = 0.94** respectively, while organic-P fraction showed highest correlation coefficient value (r = 0.98**) among all the phosphorous fractions which might be due to its higher content in the soil resulting into higher contribution in tuber yield. The saloid-P which was present in very minor quantity reported lowest correlation value (r = 0.59**) which may be due to its smallest quantity in soil as compared to other forms. Mahmood *et al*. (2020) also mentioned a positive and significant correlation of phosphorous fractions with yield of wheat crop.

It was observed from the data that the significant and negative correlation was recorded in respect of bulk density, negative and non-significant correlation was recorded in respect of particle density while significant and positive correlation was recorded in respect of porosity and maximum water holding capacity of soils for most of phosphorous fractions. Regarding the correlation of phosphorous fractions with chemical properties of soil a positive and significant correlation was observed for pH of soils except for residual-P where non-significant correlation was observed. However, a highly non-significant and negative correlation was observed in case of electrical conductivity of soils for all inorganic and organic phosphorus fractions of soil except Al-P fraction which might be due to non-significant observations reported in electrical conductivity of soils throughout the crop growth.

The data pertaining to correlation of phosphorous fractions with available macronutrient status and organic carbon content at harvest of yam bean clearly showed a significant and positive correlation for almost all the phosphorous fractions except for saloid-P in case of available P_2O_5 where positive and non-significant correlation was observed (r = 0.23). Similar results were reported by Lungmuana *et al.* (2012) who observed non-significant correlation of saloid- P and residual-P with Bray-P in red lateritic soils under rice crop.

Conclusion

The present study inferred that increasing levels of phosphorous along with increasing levels of FYM significantly increases inorganic and organic forms of nitrogen and phosphorous over sole application of inorganic fertilizers. The nitrogen and phosphorous recovery efficiency was higher in treatment receiving highest level of nitrogen (120 kg ha^{-1}) and phosphorous (80 kg ha^{-1}) along with highest level of FYM (20 t ha^{-1}). Different nitrogen fractions significantly and positively correlated with yam bean yield denoting significant increase in yield along with increased nitrogen fractions under treatment variations. Among the active forms of phosphorous Fe-P contributed maximum in availability of phosphorous and reductant soluble-P was the dominant fraction for the release of P in lateritic soils of Konkan region.

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